

# APPARATUS AND METHOD FOR MEASURING CURRENT FLOW IN AN ANIMAL OR HUMAN BODY

## BRIEF DESCRIPTION OF THE INVENTION

This invention relates generally to measuring and analyzing current flow through an animal or human body. More particularly, this invention relates to a portable contact meter analysis device.

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## BACKGROUND OF THE INVENTION

For the purposes of this patent, contact current is defined as the current that flows in an animal or human subject when the subject touches (contacts) two different electrically conductive points in the subject's environment. Different conductive points with different voltage potentials cause current to flow in the living body.

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Most current measurement systems use one of two basic methods. The first method is to insert a known impedance into the current path and measure the voltage across the known impedance. (Current, voltage, and impedance are all related by Ohm's law, which states that  $\text{Voltage} = \text{Current} \times \text{Impedance}$ . With two known quantities, one can calculate the unknown quantity, current in this case.) The second method is to attach a coupling transformer around the current path and measure the current via the magnetic field generated from the current flow.

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Both methods have significant disadvantages for a contact meter; and at present there are no devices available to measure this contact current. The first method requires that the current path be broken with a fixed impedance and that the fixed impedance not significantly alter the measured current. For contact current, the points of contact can be anywhere on the body. The current flow will generally occur throughout the volume of the body. Contact points can occur at more than two

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locations with different voltages at each point. Consequently, it is difficult to gather and process this information.

The second measurement method (using a transformer) also has a number of disadvantages. Current transformers of this type are usually insensitive and must be used with large primary currents (Amps). Contact currents are typically small, milliamps (mA) and microamps (uA), and need a sensitive measurement device. Sensitivity can be increased by increasing the size and weight of the transformer, but this makes the devices too cumbersome for human use. Thus, prior art devices have not successfully measured contact current.

An additional problem is that the transformer method measures the magnetic field created by the current. Environments with potential contact currents often have ambient magnetic fields. The transformer measures both the magnetic field from the current flow and the ambient magnetic field, and cannot differentiate the two sources.

Accordingly, it is desirable to provide an improved technique for measuring current flow in an animal or human body.

### **SUMMARY OF THE INVENTION**

An apparatus for measuring contact current includes data acquisition circuitry with at least two sensor contacts to measure the voltage drop across an animal or human body. A portable data processing unit is connected to the data acquisition circuitry to process the voltage data to produce current flow data.

The invention provides a compact, lightweight, low-power device that can be used to flexibly and non-invasively determine the magnitude of current flowing through an animal or human body.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

For a better understanding of the invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 illustrates a contact meter analysis apparatus in accordance with an embodiment of the invention.

FIGURE 2 illustrates the data acquisition circuitry channels in accordance with an embodiment of the invention.

FIGURE 3 illustrates a channel of the acquired data conditioning circuitry in accordance with an embodiment of the invention

Like reference numerals refer to corresponding parts throughout the drawings.

## 5 DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates a contact meter analysis apparatus 100 constructed in accordance with an embodiment of the invention. The contact meter analysis apparatus 100 includes data acquisition circuitry 102 and a portable data processing unit 104. To make the unit portable, a preferred embodiment of the invention includes  
10 an autonomous power source 124. In an embodiment of the invention, the portable data processing unit 104 includes acquired data conditioning circuitry 112 to receive data from the data acquisition circuitry 102. As its name implies, the acquired data conditioning circuitry 112 pre-processes and digitizes the data so that it is in a format useful to the remainder of the circuitry in the portable data processing unit 104.

As indicated in Figure 1, the acquired data conditioning circuitry 112 and data  
15 input interface circuitry 114 apply digital signals to the system bus 126. The data input interface circuitry 114 preferably includes an input mechanism, such as a keypad. A central processing unit (CPU) 116, data output interface circuitry 118, and memory 130 are also connected to the system bus 126. The CPU 116 executes the  
20 programs stored in memory 130. The data output interface circuitry 118 receives digital signals from the system bus 126 and is connected to a display 122, preferably an LCD, and a removable memory 120, preferably a compact flash memory. The memory 130 stores a set of executable programs and data, including: an initiate logging routine 132, an adjust threshold routine 134, a parameter calculator 136,  
25 generic body impedance data 138, accumulated body impedance data 140, current flow data 142, voltage data 144, and an output module 146. The programs and data stored in memory 130 are described in connection with Figure 2 and Figure 3.

Figure 2 illustrates an embodiment of the data acquisition circuitry 102 and acquired data conditioning circuitry 112 that utilizes four channels. The electrically  
30 conductive skin contacts 210A, 210B, 210C, and 210D, hereinafter referred to collectively as contacts 210, correspond to respective channels of the data acquisition circuitry 102. The contacts 210 are preferably made with skin patches commonly used for medical measurements. The contacts 210 are placed on an animal or human body

202 and are connected via connections 220A, 220B, 220C, and 220D, hereinafter referred to collectively as connections 220, to the conditioning circuitry channels 230A, 230B, 230C, and 230D, hereinafter referred to collectively as channels 230, or individually as a channel 230. The channels 230 make up the acquired data

5 conditioning circuit 112. In one embodiment of the invention, the connections 220 are cables. The invention encompasses both wireless and physical connections.

In general, an overall model of the body's impedance would have high impedance and high variability for the contact areas, skin, and extremities (fingers, hands, feet, toes, head, etc.); and low impedance and low variability for the torso, legs, 10 and arms. In a preferred embodiment of the invention, the contacts 210 are placed on the legs, torso, or arms so that the voltage measured is across the arms, legs, and torso to reduce the impedance variability. Note that in Figure 2 the contacts 210 are placed on both arms and both legs of living body 202.

Figure 3 illustrates an embodiment of a channel 230 (see Figure 2). The 15 channel 230 includes a low noise amplifier 302 that buffers the signal and protects the circuitry from outside noise and disturbances. In addition, the low input current (e.g., 10 picoamps (pA)) of the instrument reduces errors from the high impedance contacts 210 (see Figure 2). The low noise amplifier 302 amplifies the signal. The signal is bandpass filtered through a high pass filter 304 and a low pass filter 306. After the 20 low pass filter 306, the processed signal is fed to an analog to digital converter (A/D) 310 to digitize the signal and to an adjustable threshold detector 308. The adjustable threshold routine 134, discussed below, operates to adjust the adjustable threshold detector 308 for each channel 230. The adjustable threshold detector 308 preferably disregards signals between the positive and negative threshold levels at which it is set. 25 The digital output of the analog to digital converter 310, a basic voltage measurement, is applied to the system bus 126 for use by the CPU 116.

In a preferred embodiment of the invention, the output module 146 generates menus that are displayed on display 122. A user selects items on the menu or enters input through the data input interface circuitry 114 to control the behavior of the 30 executable programs stored in memory 130. When so ordered by the user, the output module 146 preferably writes data to the removable memory 120 or to the display 122. In this way, the user can, for example, write current flow data 142 to the removable memory 120 and access that data on a different machine.

In a preferred embodiment of the invention, when the adjust threshold routine 134 is selected, the output module 146 prompts the user through the display 122 for a threshold value for a channel 230. The user may enter threshold values for one or all of the channels 230 through the data input interface circuitry 114. The adjust

5 threshold routine 134 sets the adjustable threshold detector 308 to the threshold values input by the user.

Studies have measured impedances at various locations on the body and the ranges of values and averages for different sized individuals are available. The memory 130 preferably contains generic body impedance data 138 from such studies.

10 Thus, generic body impedance data 138 contains estimated impedances for the living body 202. Preferably, this data includes data for bodies of different heights and weights.

When a user indicates through the data input interface circuitry 114 that the logging is to begin by pressing the appropriate key or sequence of keys, the data input  
15 interface circuitry applies a signal to the system bus 126 that the CPU 116 recognizes as an initiate logging command. The CPU 116 then executes the initiate logging routine 132. The initiate logging routine 132 starts logging voltages measured through the data acquisition circuitry 102 and conditioned by the acquired data conditioning circuitry 112. The voltages are stored as voltage data 144 in memory 130. The  
20 voltage data 144, as well as the current flow data 142 and accumulated body impedance data 140, could also be processed immediately, without storing to memory 130. In that case, the parameter calculator 136 would be run concurrently with the initiate logging routine 132, rather than subsequently, as discussed below for illustrative purposes.

25 Utilizing Ohm's Law,  $\text{current} = \text{voltage} / \text{impedance}$ , the voltage data 144, and the generic body impedance data 138, the parameter calculator 136 calculates current through an animal or human body 202. Voltage from the voltage data 144 and impedance from the generic body impedance data 138 are available. The results of the calculation are stored as current flow data 142. Note that "known impedances," for the  
30 purposes of this calculation, are from the generic body impedance data 138 and are, in the strictest sense, estimates.

The parameter calculator 136 also utilizes Ohm's Law for the purpose of measuring impedance for the living body 202. The user sets current flow data 142 to a

known value and runs a current with that known value through the living body 202. Preferably, additional contacts are used for this purpose. Voltage data 144 is accumulated as previously described. The parameter calculator 136 calculates impedance = voltage / current for the current represented in current flow data 142 and the voltage represented in voltage data 144. The calculated impedance is stored in accumulated body impedance data 140.

Utilizing Ohm's Law, current = voltage / impedance, the voltage data 144, and the accumulated body impedance data 140, the parameter calculator 136 calculates current through an animal or human body 202. Voltage from the voltage data 144 and impedance from the accumulated body impedance data 140 are available. The results of the calculation are stored as current flow data 142. Because impedance for each living body 202 is slightly different, calculating known impedances for an animal or human body 202 will generally result in more accurate current flow measurements than using the generic body impedance data 138.

Preferably, the data input interface circuitry 114 includes a button to stop the logging process initiated by the initiate logging routine 132. This button functions as a kill switch or cancel button.

The foregoing description, for purposes of explanation, used specific nomenclature to provide a thorough understanding of the invention. However, it will be apparent to one skilled in the art that the specific details are not required in order to practice the invention. In other instances, well known circuits and devices are shown in block diagram form in order to avoid unnecessary distraction from the underlying invention. Thus, the foregoing descriptions of specific embodiments of the present invention are presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, obviously many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.